

One Mast Offset, Two Different Camera Angles

A moving camera does not always turn



Nearby and distant features shift differently when a camera moves sideways without turning.

Imagine watching a water tower beyond a nearby railing. Move the camera sideways while keeping its direction fixed. The tower and railing shift by different amounts in the picture. Now turn the camera without moving its centre. The view changes again, for a different reason.

These are two separate motions. Translation changes where the camera sits. Rotation changes the camera's orientation; some rotations redirect its optical axis. In a perspective camera, the image motion caused by translation depends on scene depth; the rotational component does not. This distinction is built into the [NIST camera-motion model](#).

Take a calculated example: a camera slides 12 mm sideways, perpendicular to its viewing direction, with no rotation. A fixed feature initially straight ahead at 20 m

changes bearing by about 0.60 mrad. At 1,000 m, the change is only 0.012 mrad. The relation is $\arctan(\text{sideways shift} / \text{distance})$. Here, one milliradian is one thousandth of a radian.

A bending mast can produce both motions together. Measuring its tip position answers only the first question. To know the second, we need the mounting plate's orientation and the camera's orientation relative to that plate.

A tempting shortcut is to divide the tip movement by mast height. That gives the small angle of a straight line joining the base to the tip: the chord. A camera fixed to the top follows the local section's angle. A curved mast does not generally share one angle along its length.

Tip position and camera direction are different quantities.

A 12 mm bend is not a 2 mrad tilt

Start with a deliberately simple model: a straight, uniform 6 m beam, fully fixed at its base and free at its top. Assume small, elastic bending in one plane, negligible shear deformation and a rigid camera attachment. A horizontal force acts only at the tip. These conditions matter: [Euler-Bernoulli beam theory](#) ties section rotation to the local slope of the bending curve.

For this load case, the magnitudes are:

- Tip movement: $\delta = P L^3 / (3 EI)$
- Tip angle: $\theta = P L^2 / (2 EI)$
- Therefore: $\theta = 3\delta / (2L)$

P is the tip force and L is beam length. EI is bending stiffness: material stiffness multiplied by the cross-section's second moment of area. The [MIT derivation](#) obtains displacement and slope separately.

Choose $EI = 180,000 \text{ N}\cdot\text{m}^2$ and $P = 30 \text{ N}$. The calculated tip movement is 0.012 m, or 12 mm. The top rotates by 0.003 rad, or 3.00

mrad. Dividing 12 mm by 6 m would give 2.00 mrad: one-third below the actual tip-angle result for this model.

Plate rotation does not automatically equal optical-axis deflection: rotation about the viewing axis rolls the image without changing that axis. The viewing direction matters.

For rotation perpendicular to the viewing axis, 3 mrad shifts its intersection about 3 m across a plane 1,000 m away, initially perpendicular to the view. Pure sideways translation by 12 mm shifts the intersection by 12 mm. These separate geometric examples show why position and orientation cannot be interchanged.

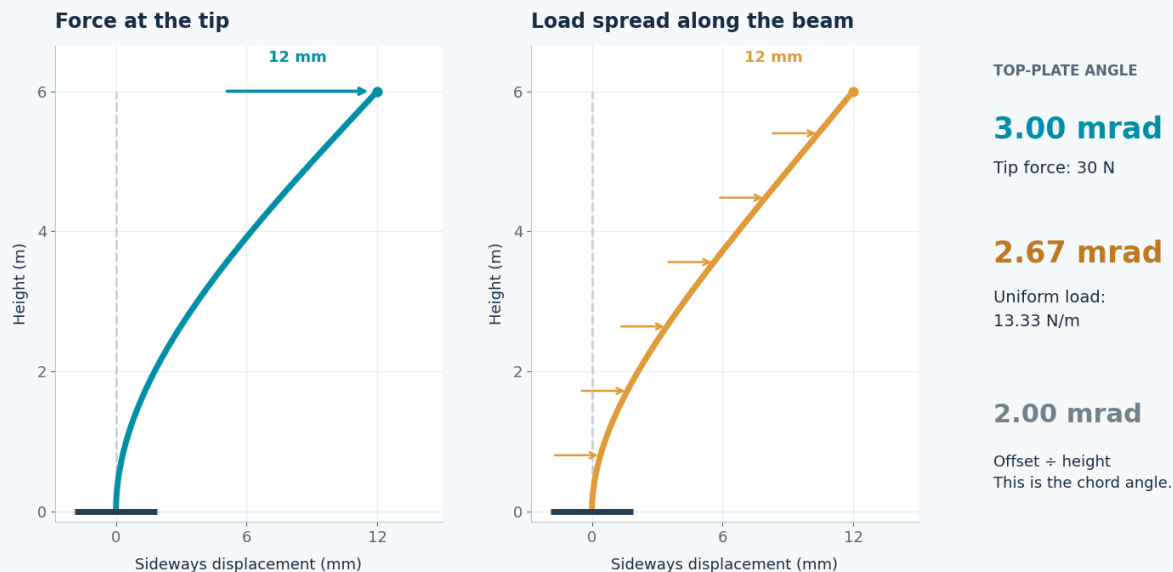
These are geometry and beam calculations with chosen inputs. They do not predict the response of a particular telescopic mast.

For a uniform beam with a tip force, $\theta = 1.5 \times \delta/L$.

Move the load, change the answer

The same 12 mm offset can hide different angles

Calculated examples • 6 m uniform beam • fixed base • small elastic bending



Shape matters: a straight line from base to tip is not the tangent at the top.

$EI = 180,000 \text{ N}\cdot\text{m}^2$ in both cases. Displacement is magnified by the unequal axis scales; do not measure angles from the drawing.
Original calculation using small-deflection beam equations. These values are not mast product ratings.

The same 6 m beam and 12 mm tip movement produce different top angles under a tip force and a uniform load.

Spread the sideways load evenly along the same fixed-base beam. The length and bending stiffness stay unchanged; the force now acts along the structure instead of only at the tip.

For a uniform load q in newtons per metre, tip movement is $\delta = q L^4 / (8 EI)$, and tip angle is $\theta = q L^3 / (6 EI)$. Dividing these results gives $\theta = 4\delta / (3L)$.

[Sathyabama's beam notes](#) work through this load case. With our chosen stiffness, $q = 13.33 \text{ N/m}$ produces the same 12 mm movement, but a top angle of 2.67 mrad. The total force is 80 N: spreading force lower down requires more total force to produce this tip movement.

Two equal offsets therefore hide a 0.33 mrad difference in plate orientation, corresponding to roughly 0.33 m at a plane 1,000 m away. Neither beam has the chord shortcut's 2.00 mrad tip angle.

Vibration adds another shape question

A gust need not produce a sequence of identical static curves. Bending modes describe characteristic shapes, each with an amplitude that varies with time. Their contributions add together: tip displacement adds their tip movements; tip slope adds their local slopes. Those sums need not stay in a fixed proportion. The [University of Nebraska beam study](#) explains this superposition.

A sideways-motion trace alone cannot establish camera-angle motion without a validated structural relationship. Low tip displacement may coexist with local rotation when different contributions partly cancel in displacement.

The load pattern determines the displacement-to-slope relationship.

Measure the plate, then check the view



Two separated targets reveal the top plate's position and its rotation in a known plane; the base provides a separate reference.

A useful test records three things together: movement of the support, orientation of the mounting plate, and the camera's view of fixed scene features. Time alignment matters because a plate-angle sample taken between image exposures may describe a different instant.

For motion confined to one known plane, track two separated points on a rigid top plate against a stable external reference. Their midpoint provides one plate position; the changing direction of the line between them describes rotation. With 0.40 m separation, a 3 mrad rotation gives about 1.2 mm of differential movement perpendicular to that line. This is a calculated scale for choosing measurement capability, not an acceptance limit. Full three-dimensional orientation needs additional geometric information, such as three non-collinear points tracked in three dimensions.

Record the base too. If the external reference moves with the support, apparent stability can be misleading. Keep camera zoom, exposure and image-stabilisation settings fixed during comparisons; record each setting so another run has the same meaning.

Interpret the paired records:

- Plate angle changes with the view: investigate support rotation and the camera's response to it.
- Tip position changes while plate angle stays steady: look for translation and depth-dependent scene movement.
- The image moves without corresponding plate motion: examine camera commands, attachment movement and the image chain before blaming mast bending.

Real telescoping joints, guying, base flexibility and payloads can change the model. NASA's [Artemis modal-analysis account](#) shows why dynamic models must match the tested configuration. It supplies no universal mast-frequency target.

When reviewing an [Inventra S³ mast configuration](#), ask for the measured top-plate angle under the stated setup, alongside tip movement. The decisive question is: what moved, what turned, and did the camera follow?

Measure position, angle and image response on the same timeline.

Sources and further reading

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